



Fermi LAT Report

Fermi User Group meeting
October 11, 2017

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on behalf of the Fermi LAT collaboration

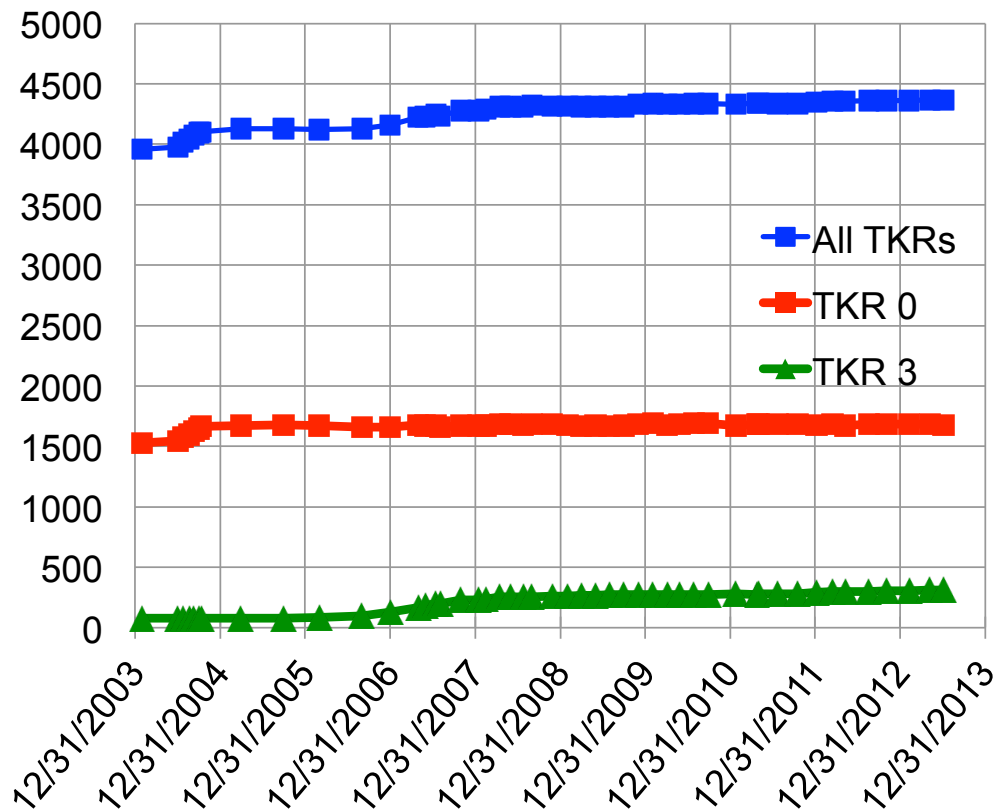
Outline

- Fermi LAT status
 - Instrument operations
 - Data processing pipelines
- Fermi Lat Source Catalogs - 4FGL in preparation: see next talk
- Pass 8 complete

Fermi LAT status

- The LAT continues to operate well with no degradations in science performance.
 - 111 billion events downlinked to the ISOC
 - 1.05 billion source photons available at the FSSC
- The International Fermi LAT Collaboration continues to provide excellent coverage for all LAT instrument operations and data processing/analysis needs
 - good coverage in all areas due to multitasking by many collaboration members
 - collaboration actively engaged in data quality monitoring;
 - key commitments from partners for extended operations remain firm

LAT Tracker Status – 4,632 (0.52%) Hot or Dead Strips



12 FM6 162 2	13 FM4 256 -2	14 FM10 63 0	15 FM11 66 0
8 FM5 151 1	9 FM3 345 1	10 FM7 82 1	11 FM9 56 1
4 FMB 357 -1	5 FM1 439 0	6 FM12 58 0	7 FM13 53 0
0 FMA 1680 -5	1 FM2 221 -3	2 FM14 64 0	3 FM15 314 10

Shown per tower:

- Current number of bad strips
- Change in number during 2017

- TKR hot strip checks are performed monthly
- Total of 9 new bad strips masked so far in 2017

LAT data pipeline

~400,000 lines of code generated and maintained by the LAT Collaboration

L1 processing typically requires 2 to 3 CPU years per week

- to date, ~800 CPU years
- reprocessing used additional ~560 CPU years

Many LAT team papers out...

LAT Collaboration papers

Journal	Published	In press	Total
Advances in Space Research	0+1=1	-	1
Astronomy and Astrophysics	8+61=69	0+5=5	74
Astroparticle Physics	2+6=8	-	8
Astrophysical Journal	100+112=212	0+1=1	213
Astrophysical Journal Letters	32+35=67	-	67
Astrophysical Journal Supplement	14+6=20	-	20
Astrophysics and Space Science	0+1=1	-	1
Journal of Cosmology and Astroparticle Physics	4+8=12	-	12
Journal of Geophysical Research	0+1=1	-	1
Monthly Notices of the RAS: Letters	0+2=2	-	2
Monthly Notices of the Royal Astronomical Society	0+50=50	-	50
Nature	2+1=3	-	3
Nature Physics	0+2=2	-	2
Nuclear Instruments and Methods	0+1=1	-	1
Physical Review D	11+7=18	-	18
Physical Review Letters	11+1=12	-	12
Physics Reports	0+1=1	-	1
Publ.Astron.Soc.Austral.	0+1=1	-	1
Publications of The Korean Astronomical Society	0+1=1	-	1
Publications of the ASJ	0+2=2	-	2
Science	20+0=20	-	20
Total	204+300=504	0+6=6	510

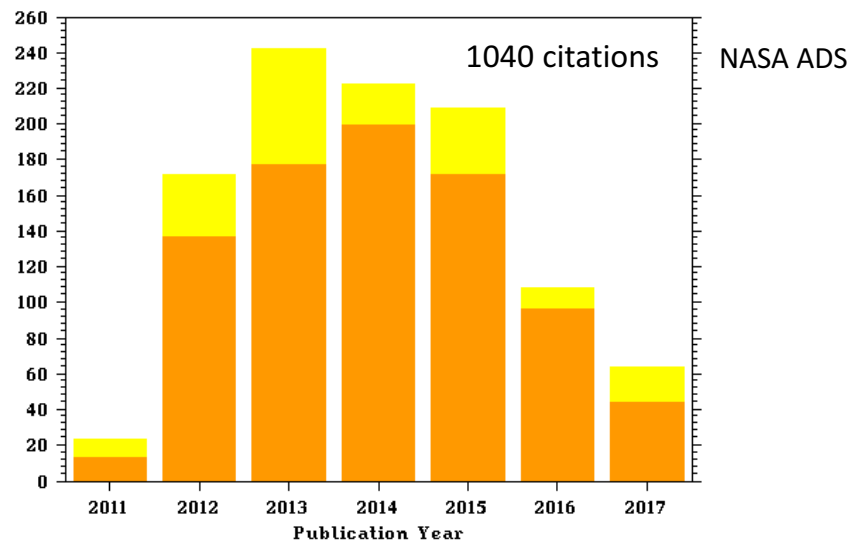
published in both physics and astrophysics journals, reflecting broad interest

<http://fermi.gsfc.nasa.gov/ssc/library/pubs/>

<http://www-glast.stanford.edu/cgi-bin/pubpub>

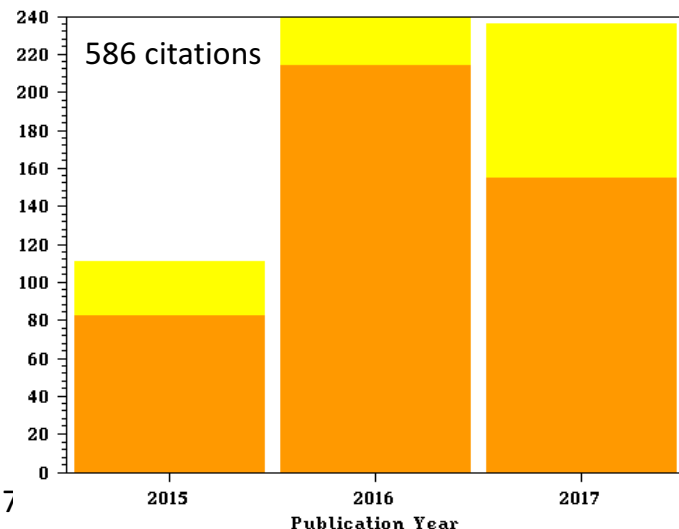
Fermi Large Area Telescope Second Source Catalog

Ap J Suppl **199**, 31 (April 2012)

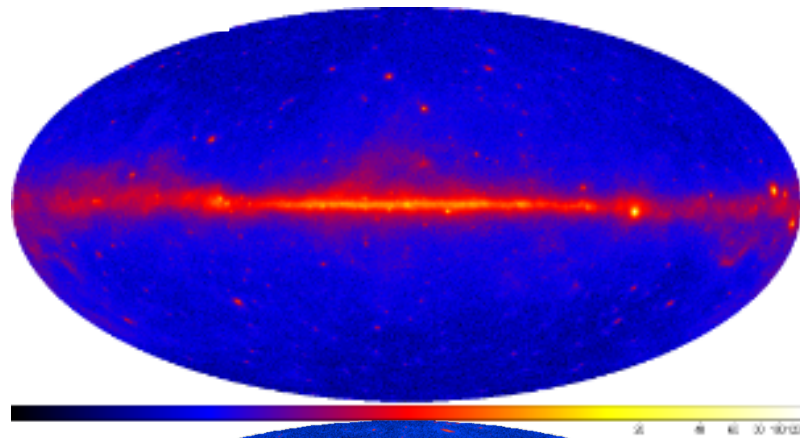


Fermi Large Area Telescope Third Source Catalog

Ap J Suppl **218**, 23 (June 2015)

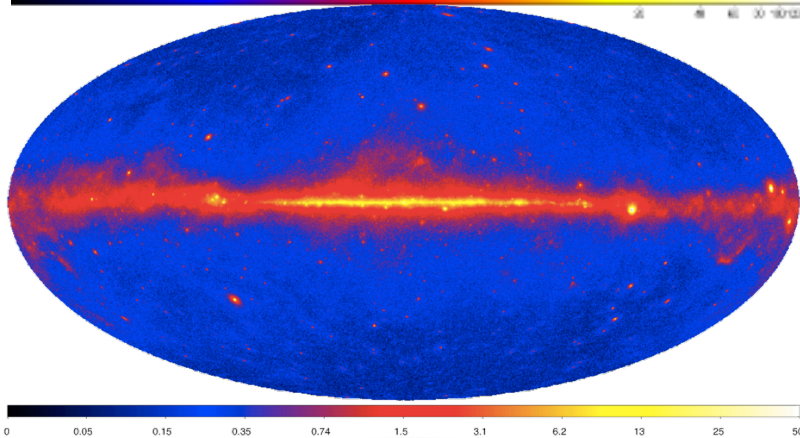
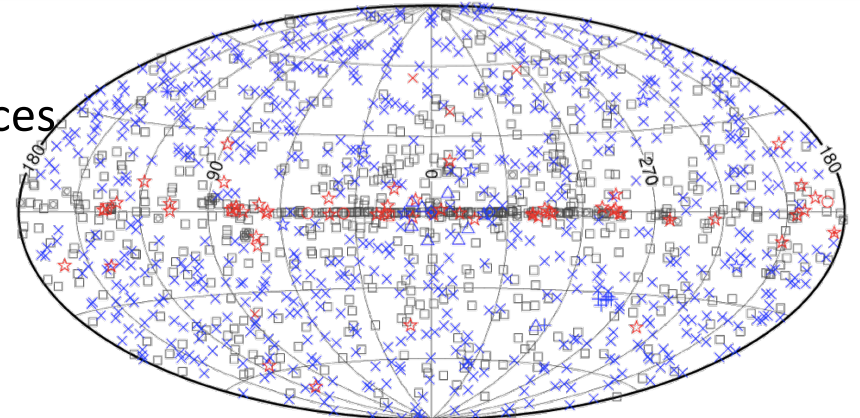


3rd Fermi LAT Catalog



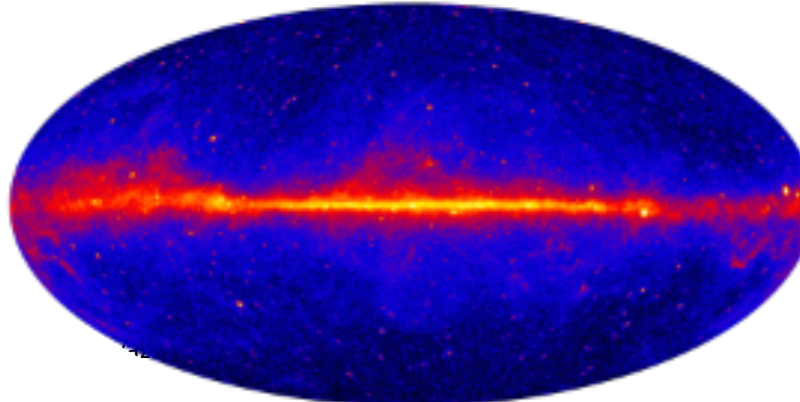
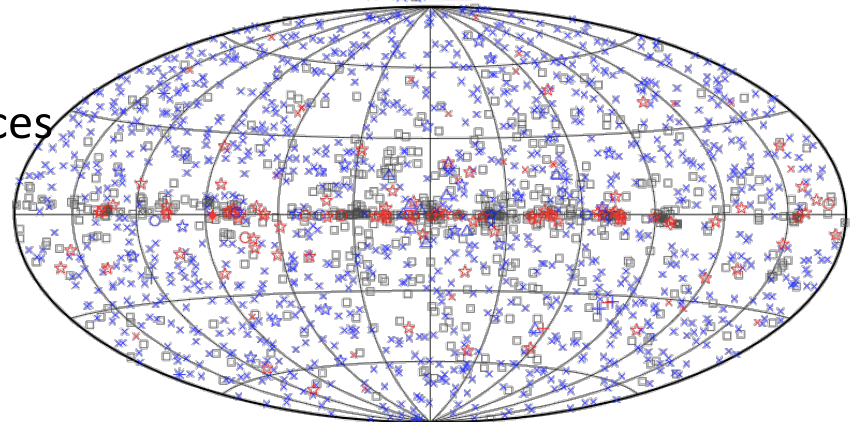
1451
sources

1FGL
11 m



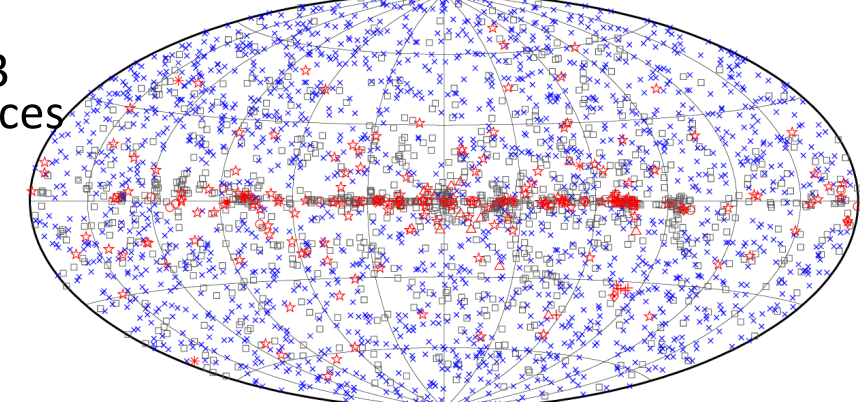
1873
sources

2FGL
2 y



3033
sources

3FGL
4 y



LAT catalogs

- In addition to the LAT source catalogs, the LAT team produces several more specialized catalogs:

Third Catalog of Active Galactic Nuclei Detected by the Fermi Large Area Telescope

ApJ, 810, 14A (2015)

Second Fermi Large Area Telescope Catalog of Gamma-ray Pulsars

ApJS, 208, 17A (2013)

First Fermi LAT Gamma-ray Burst Catalog

ApJ Suppl, 209 11 (2013)

First Fermi LAT Catalog of Sources above 10 GeV

ApJS, 209, 11A (2013)

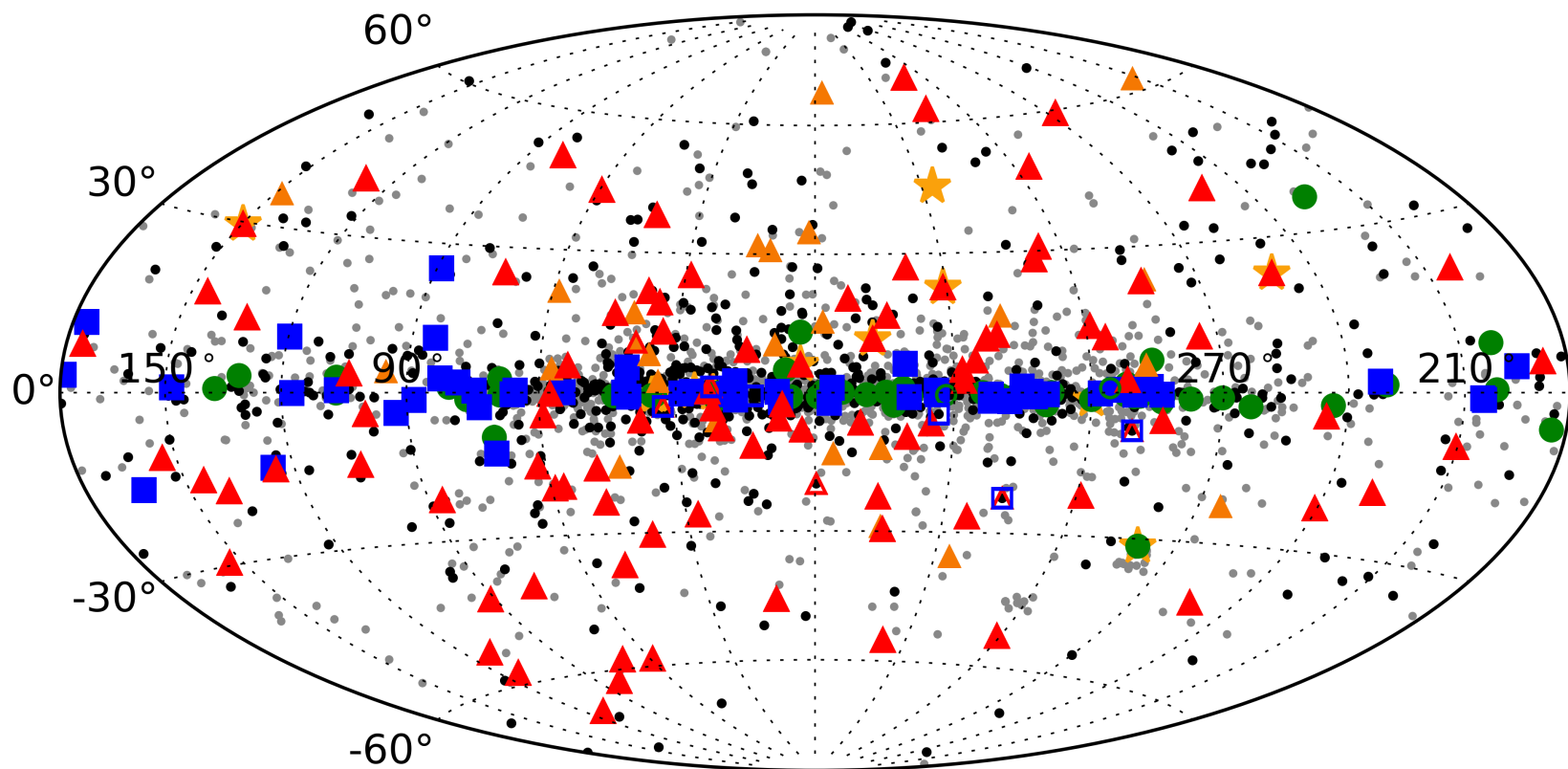
First Fermi LAT Supernovae Remnant Catalog

ApJS, 224, 8A (2016)

Third Fermi LAT Catalog of Hard Gamma-Ray Sources

ApJ, 846, 34A (2017)

Fermi LAT Pulsars and LAT-associated radio MSPs



Summary

- LAT continues to perform well
- Science reach of LAT remains high, enhanced with Pass 8
- Key LAT LAT partners remain committed for extended operations phase

National Aeronautics and Space Administration



Fermi
Gamma-ray Space Telescope

***Fermi-LAT:* science highlights and future projects**

Elisabetta Cavazzuti, Regina Caputo
ASI and GSFC

Fermi User Group meeting,
October 11, 2017

Hot topics

Multi Messenger sky:

- Neutrinos: IceCube detection with a possible AGN counterpart

Huge Sun flare

Periastron in the PSR B1259-63 system

Science overview

- Catalogs
- Pulsars
- Blazars
- Transients
- Analysis/data improvements

Science highlights

3FHL (Ajello, M. et al. 2017, ApJS, 232, 18)

Analysis details:

10 GeV – 2 TeV, 84 months of data (until August 2015)
Pass 8 (source), PSF types, unbinned likelihood

Detections:

1556 sources (vs. 514 1FHL):
133 detected by IACTs (TeVCat)
211 brand new sources (not in 1FHL/2FHL/3FGL/TeVCat)

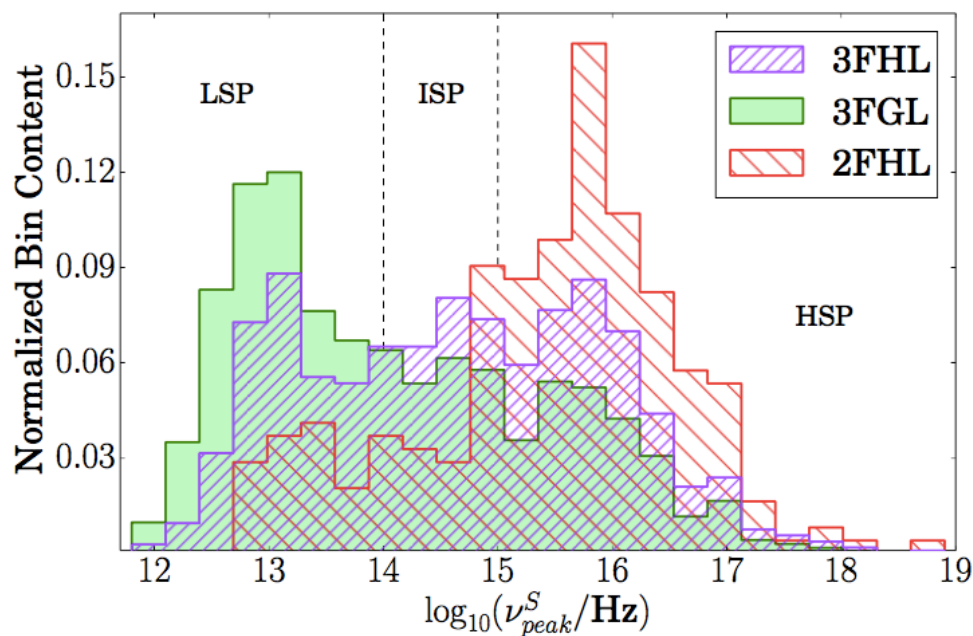
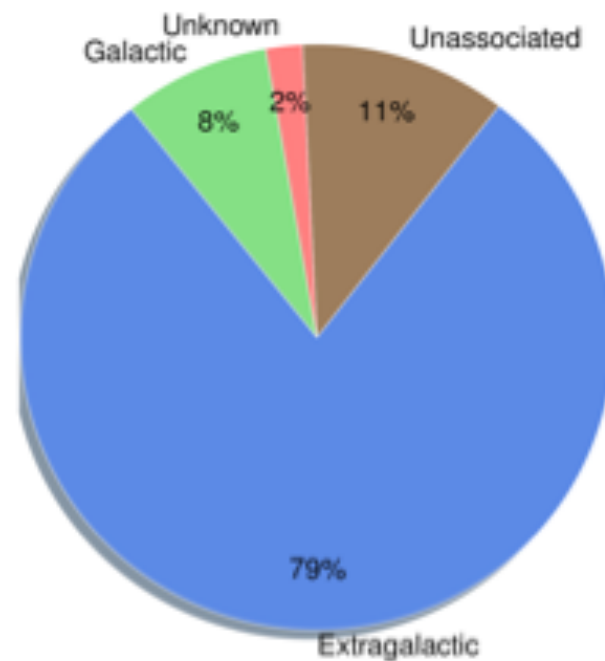


Fig. 14.— Normalized distributions of the frequency of the synchrotron peak for the blazars detected in the 3FGL (0.1–300 GeV), 2FHL (50 GeV–2 TeV), and 3FHL (10 GeV–2 TeV) catalogs.



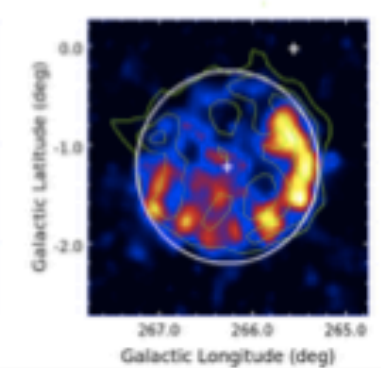
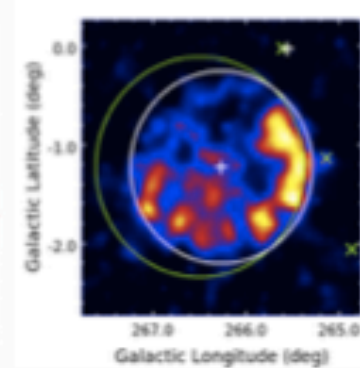
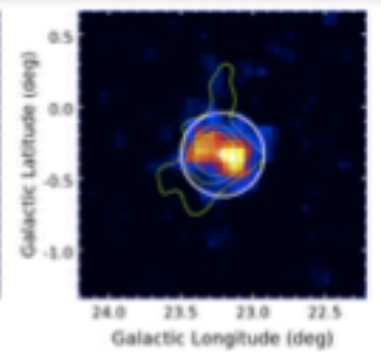
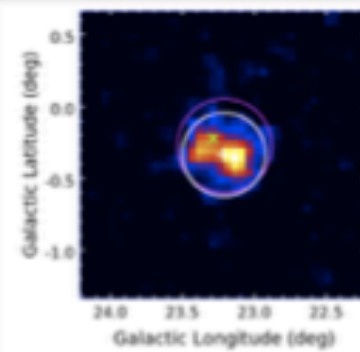
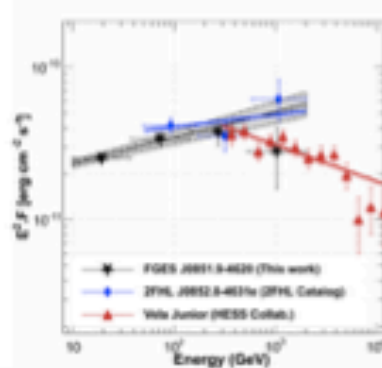
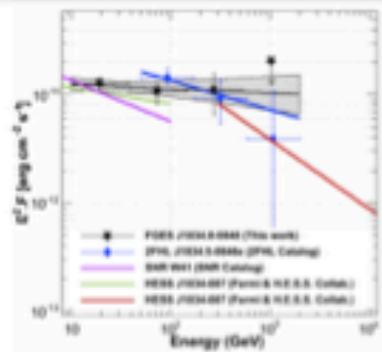
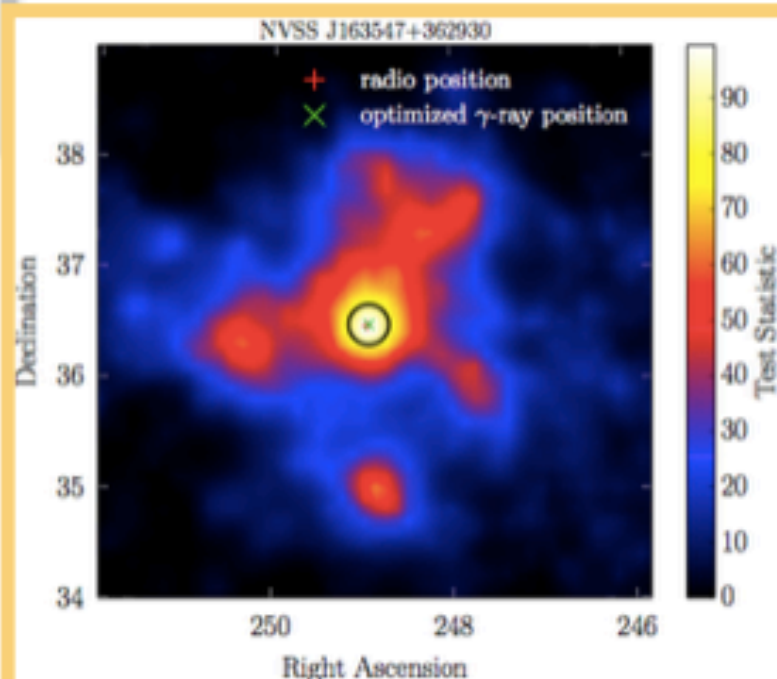
Median localization accuracy is 2.3 arcmin in radius (95%) !

Bottom line: plenty of sources to be followed with CTA. We find about 2 times more sources above 10 GeV than above 50 GeV at the same energy flux limit ($1e-12$ erg/cm²/s)

Science highlights

FGES: 46 Extended Sources
 $|\text{bl}| < 5$ deg, 6 years of data, Pass 8
 $E > 10$ GeV,
 morphological and spectral characteristics

(Ackermann, M. et al. 2017, ApJ, 843, 139)



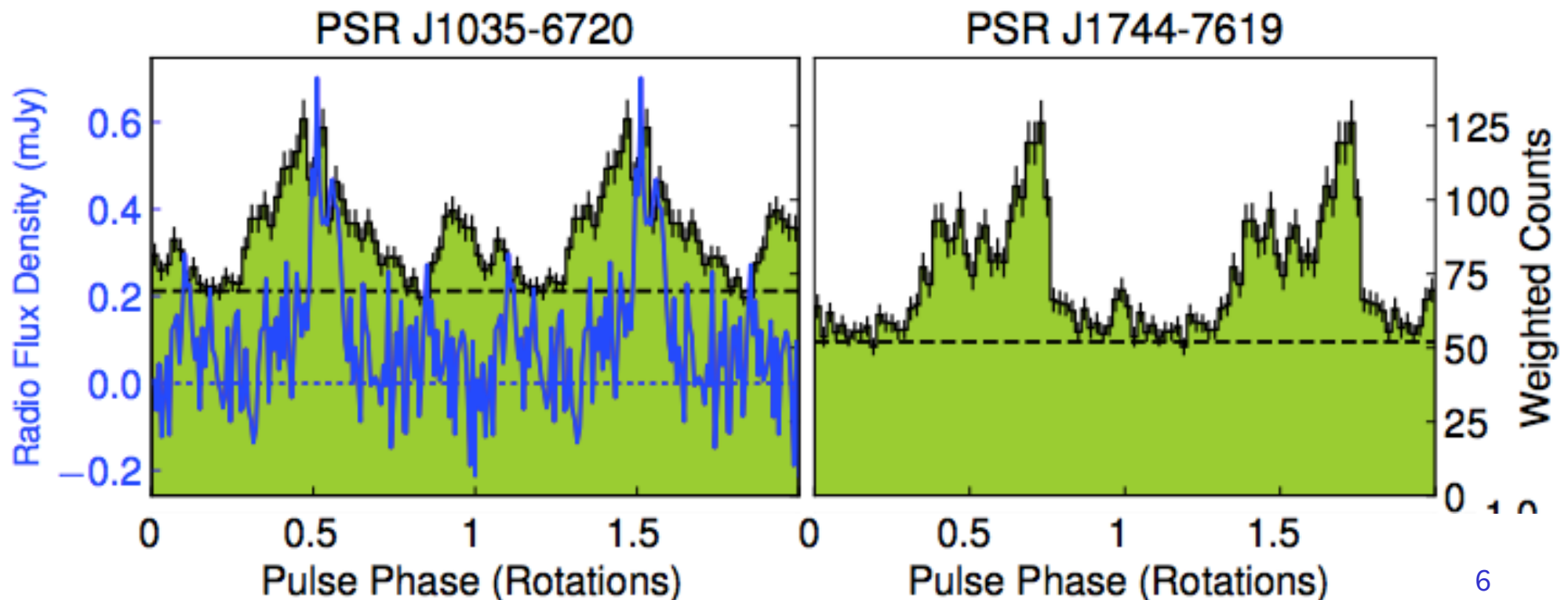
5 gamma-ray blazars within the first 2 billion years,
 Pass8, 92 months, 60 MeV - 300 GeV,
 $3.3 < z < 4.3$, $8.5 < \text{Log} M_{\text{BH}} < 9.8 M_{\odot}$ (2 over 9 M_{\odot})
 the radio-loud phase may be a key ingredient for a
 quick black hole growth in the early Universe

(Ackermann, M. et al. 2017, ApJL, 837, L5)

Science highlights

First radio-quiet MSPs found: from **Einstein@Home gamma-ray pulsar search**: found in gamma-ray searches without constraints from observations at other wavelengths:

- Important for ruling out MSP nature of dark matter candidates
- Promising for detecting isolated MSPs in the Galactic bulge, potentially explaining (part of) the GC GeV excess.



Ongoing and future projects

New catalogs in the pipeline

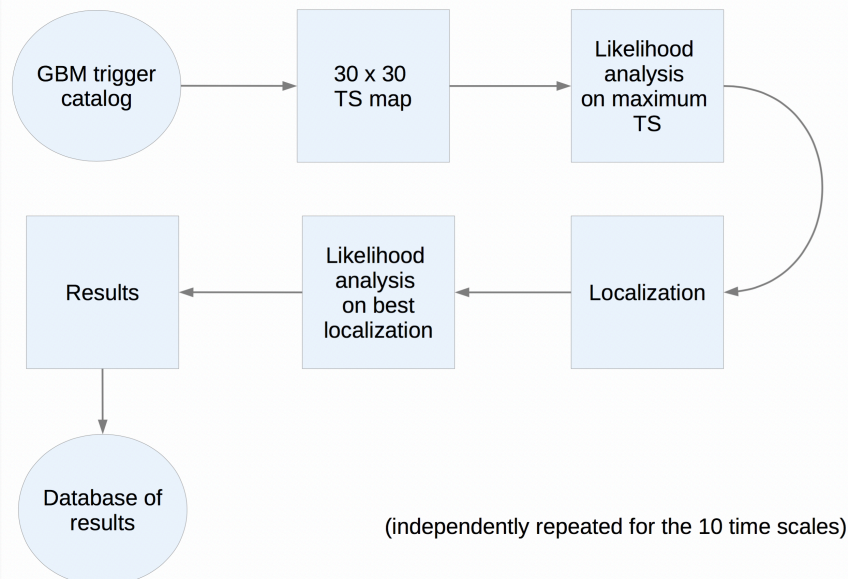
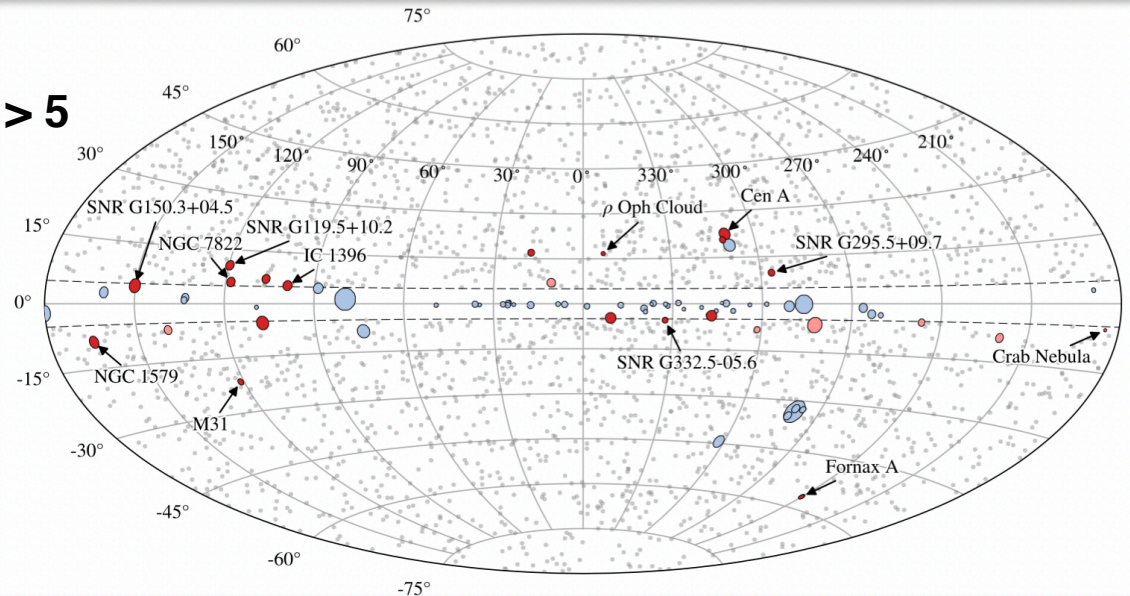
FHES: search for sources with angular extension at high Galactic Latitude ($|b| > 5^\circ$)

7.5 years, P8 data, 1 GeV - 1 TeV

24 extended sources: 5 known vs 19 new

19 new sources:

8 associated, 5 unassociated, 6 confused



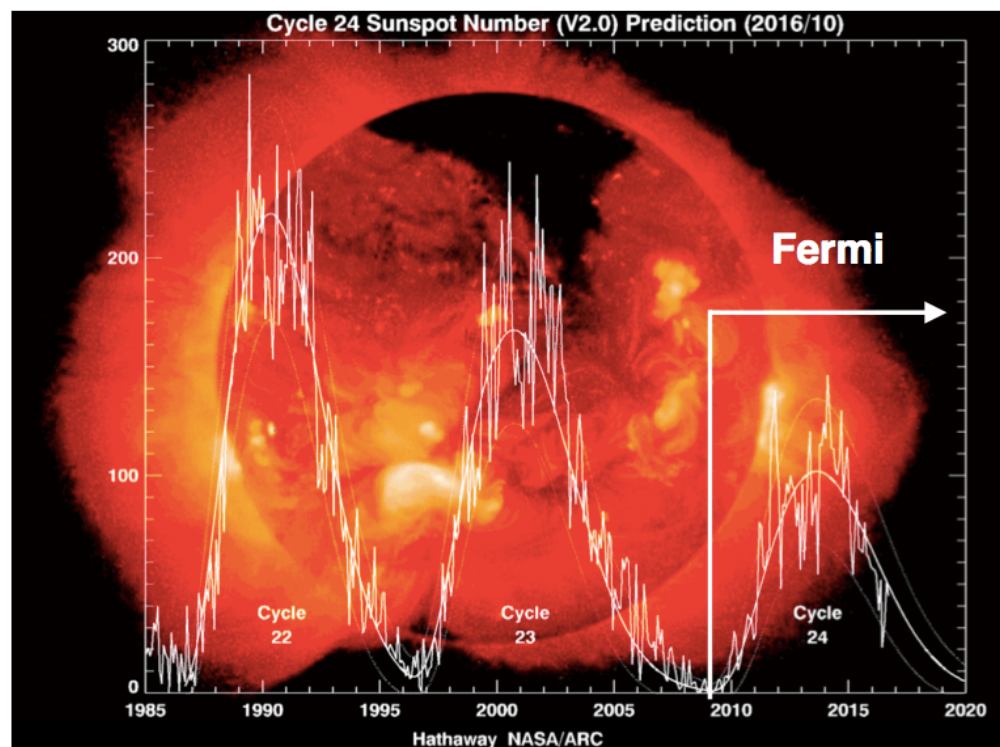
2nd GRB: 9 years of data, search on different time scales, improved localization, use of LAT transient factory,

- LLE analysis (significance, duration)
- Composite Light Curve (GBM+LLE+LAT)
- Time Resolved Likelihood Analysis (define the extended emission)
- Likelihood analysis in different time window (GBM, Extended)
- TSMAP

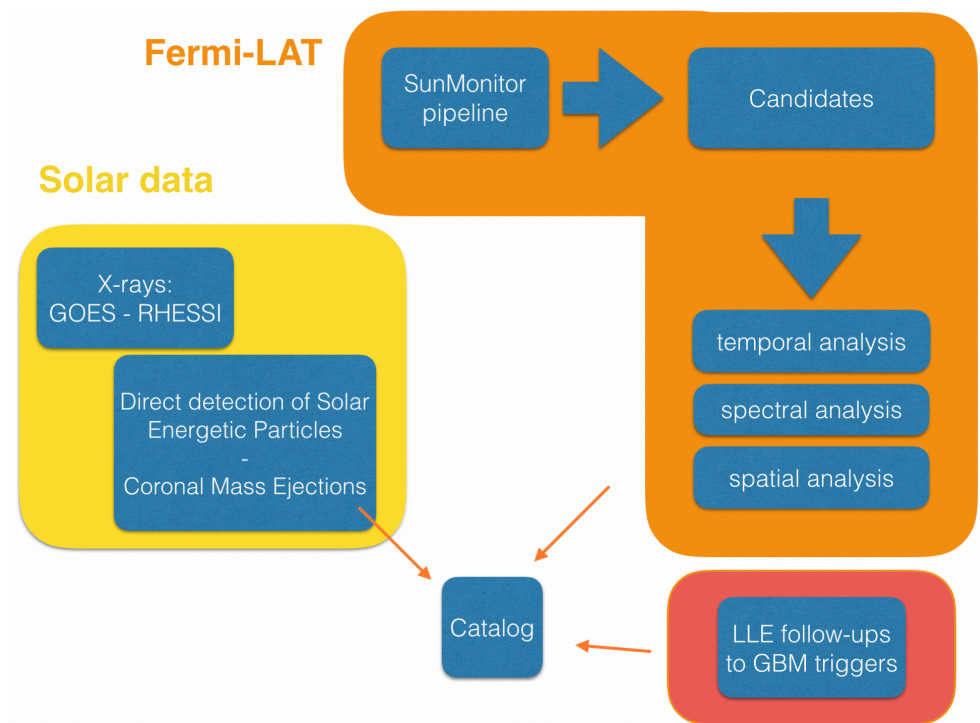
Ongoing and future projects

New catalogs in the pipeline

Solar Flares: 36 flares detected
(impulsive and long duration)... till
August 2017



About 15 detections > 50 MeV



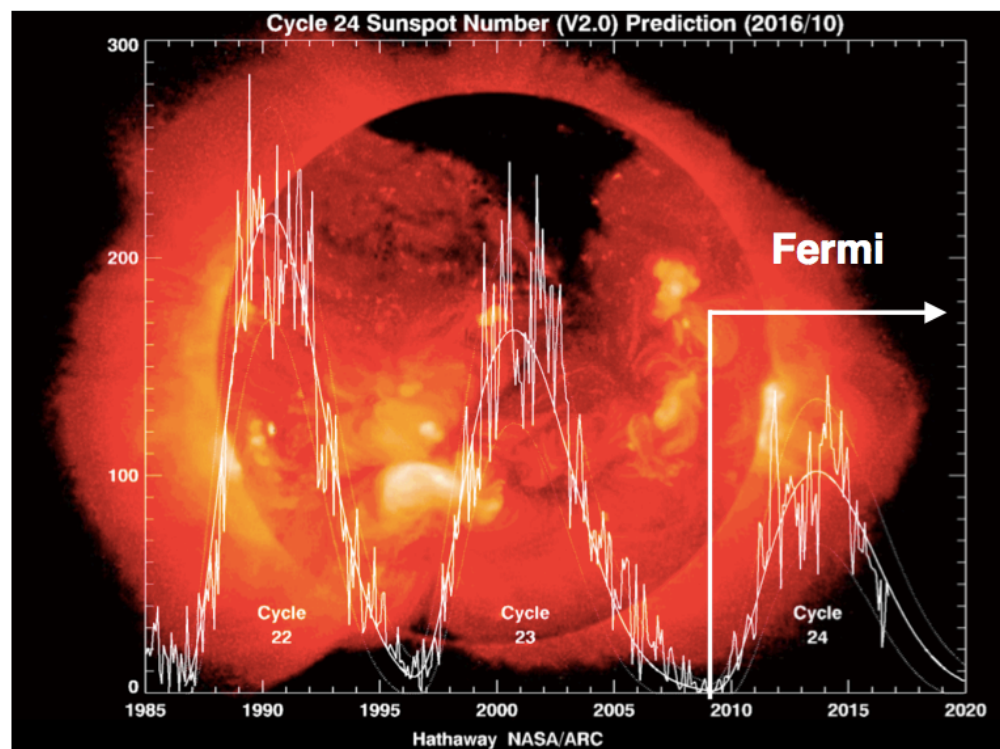
Cycle 24:

Quietest cycle in 100 years

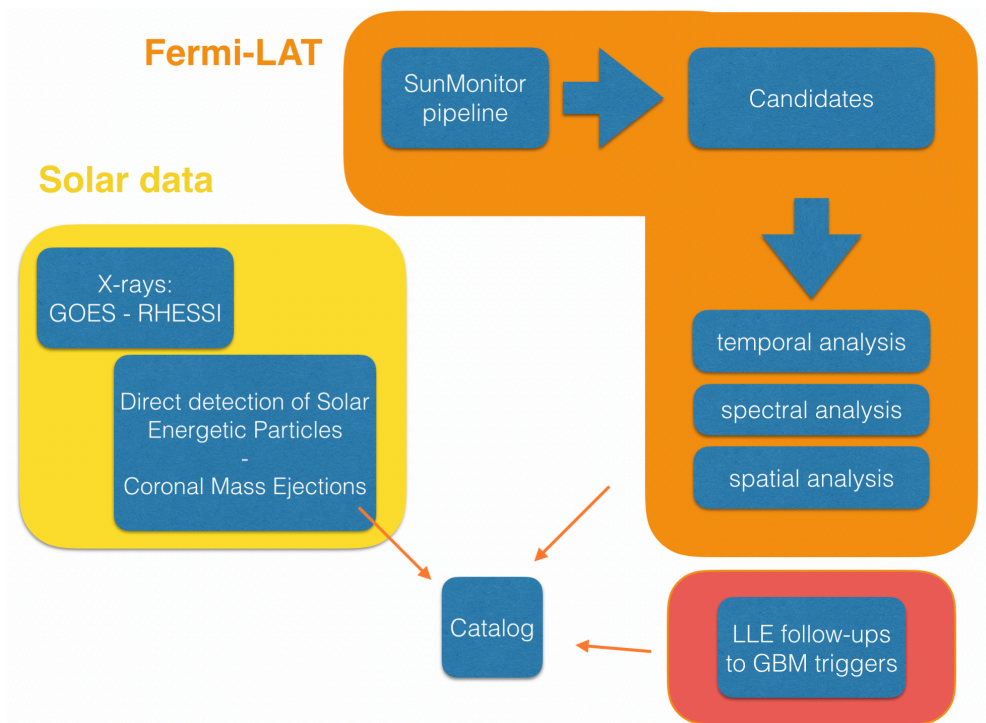
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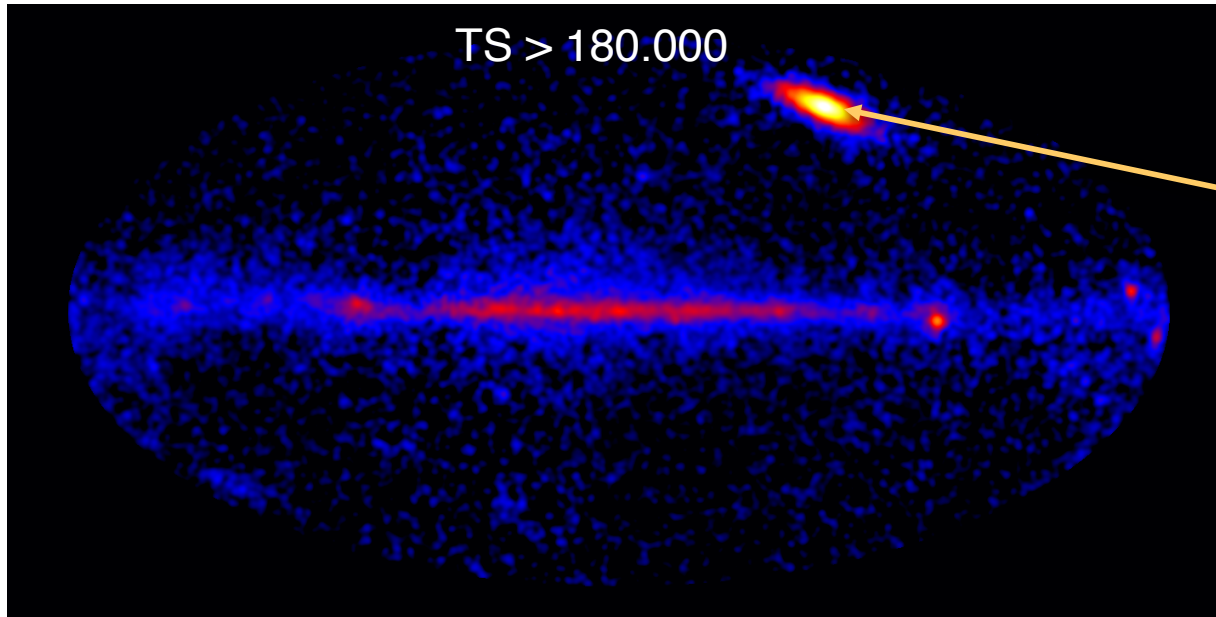


Cycle 24:

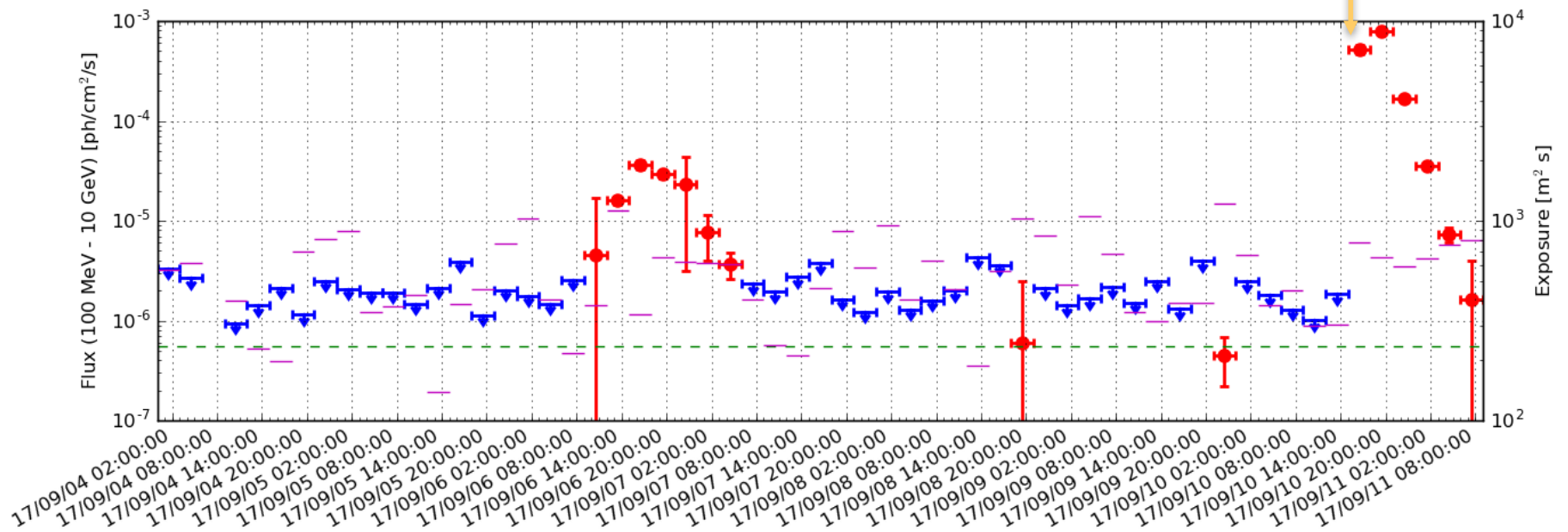
Quietest cycle in 100 years

then ... 19

Ongoing and future projects



huge flare of the Sun

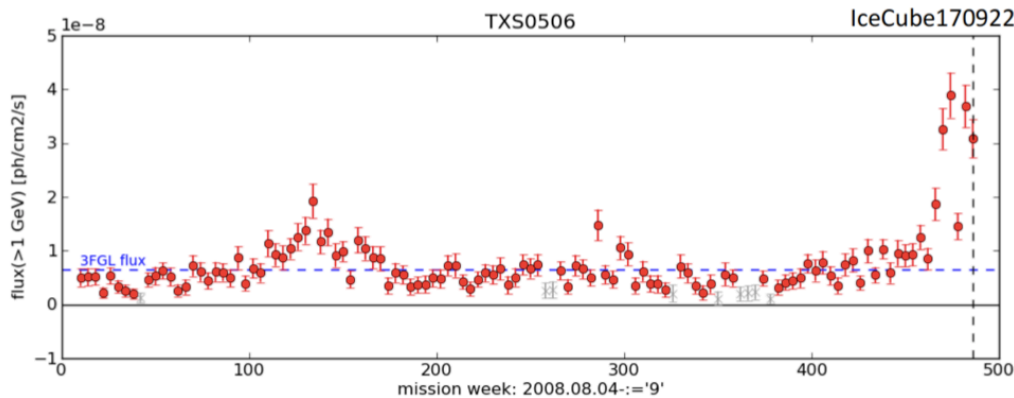


IceCube-170922A

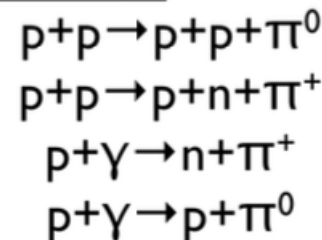
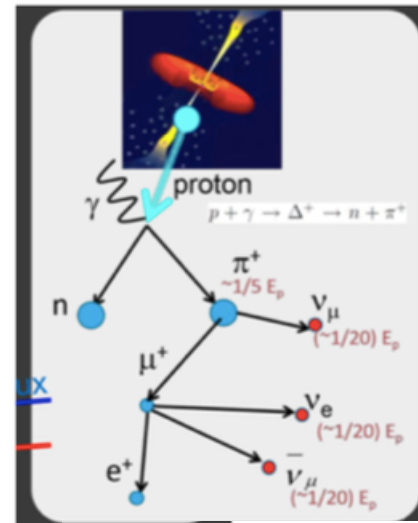
High energy neutrino (~ 100 TeV) detected by Ice Cube on September 22, 20:54:30.43 UT, 2017

Neutrinos are produced by cosmic-rays and ambient photons (p-gamma) or protons (p-p)

During the neutrino production, similar energy of photons (VHE gamma-rays) are also emitted



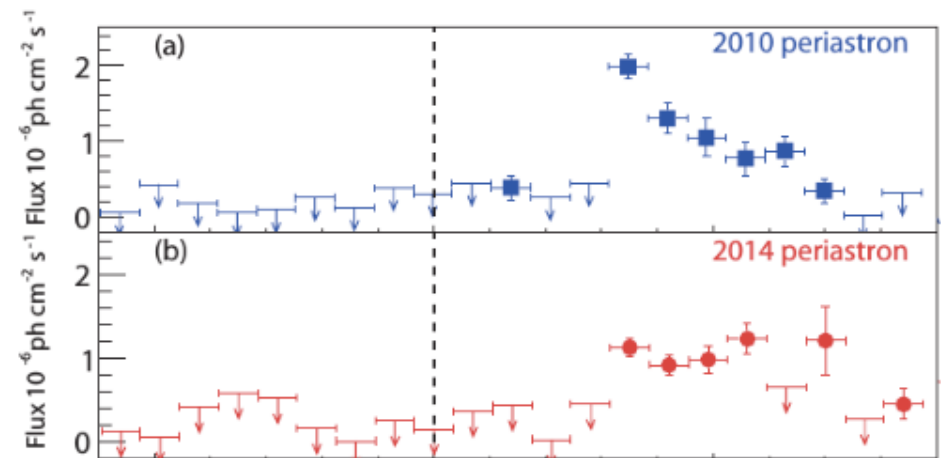
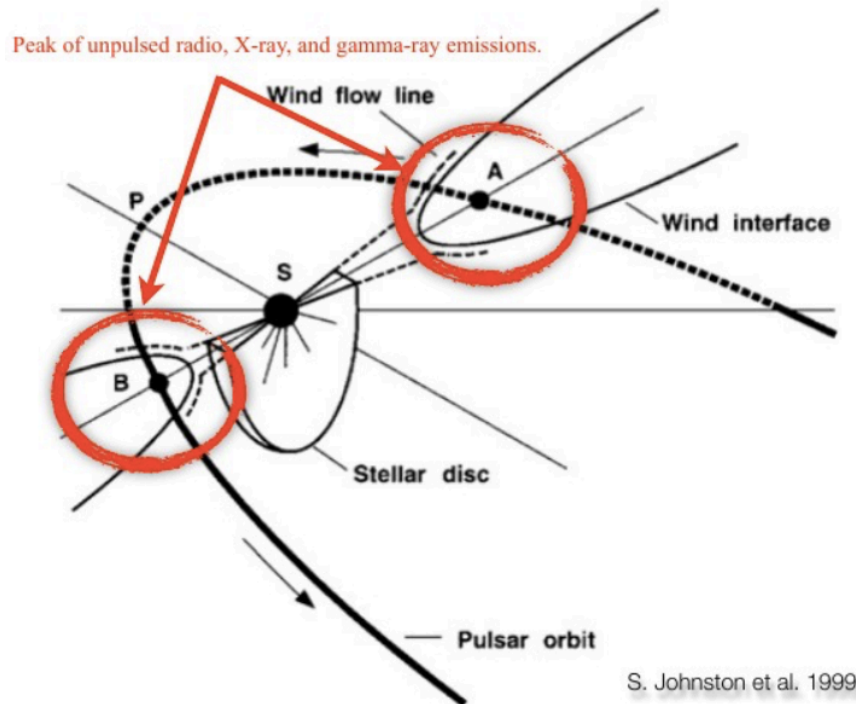
Fermi-LAT and IACT observations are important to identify the IceCube neutrino source



Related

- 10833** VERITAS follow-up observations of IceCube neutrino event 170922A
- 10831** Optical photometry of TX0506+056
- 10830** SALT-HRS observation of the blazar TXS 0506+056 associated with IceCube-170922A
- 10817** First-time detection of VHE gamma rays by MAGIC from a direction consistent with the recent EHE neutrino event IceCube-170922A
- 10802** HAWC gamma ray data prior to IceCube-170922A
- 10801** AGILE confirmation of gamma-ray activity from the IceCube-170922A error region
- 10799** Optical Spectrum of TXS 0506+056 (possible counterpart to IceCube-170922A)
- 10794** ASAS-SN optical light-curve of blazar TXS 0506+056, located inside the IceCube-170922A error region, shows increased optical activity
- 10792** Further Swift-XRT observations of IceCube 170922A
- 10791** Fermi-LAT detection of increased gamma-ray activity of TXS 0506+056, located inside the IceCube-170922A error region.
- 10787** H.E.S.S. follow-up of IceCube-170922A
- 10773** Search for counterpart to IceCube-170922A with ANTARES

Periastron in the PSR B1259-63 system



From Caliendo et al. (2015), using P7REP data.
One-week bins, vertical dashed line is periastron.

γ -ray emission is only detected in certain parts of the orbit. Together with its long orbital period (3.4 years), it was only detected in one occasion when the pulsar approached the companion star in late 2010/early 2011.

Ongoing and future projects

Fermi@10 session: Fermi-LAT in the next 10 years

The keywords for the future are

TRANSIENTS

Multi Messenger (GW, neutrino...)

Multi Wavelength sky

Time domain -> **Short** time scales: variability

Long time scales: periodicity

We have many active MW facilities: LVC, IceCube, eRosita, JWST, CTA, SKA, LSST, etc

Flare advocate and **Burst/GW advocate** are critical to our success in the time domain era

Next FGL catalog: the fourth

4FGL and 4LAC

8 years, 0.1 - 10 GeV, Pass 8,

Associations:

- ~ 7500 sources
 - ~ 3600 AGN
 - ~ 220 PSR
 - ~ 164 SNR+PWN
 - ~ 25 globular clusters

Unassociated sources: the LAT team is working on improving the association procedures and MW characterisation of the sources

—> working to **improve the interstellar emission model**: Besides the more precise LAT data, this benefits from external input, particularly recent all-sky HI surveys and the Planck dust map.

down-weighting pixels with many counts in the maximum likelihood fitting in order to account (approximately) for systematics in the source detection statistic and in the parameter uncertainties.

- * diffuse model in the very last stages
- * the projects will be presented at the coming 7th Fermi Symposium
- * the catalogs are targeted to be released before the end of this year

Next FGL catalog: the fourth

The 4FGL is targeted to be released on time for:

- ❖ GI proposals
- ❖ Fermi Symposium for 10 years of mission
- ❖ Senior Review 2019

LAT data releases and improvements

Cal-Only event class:

- The CalOnly event class utilises gamma-ray events that do not convert in the tracker - instead they are only measured in the calorimeter.
- This yields an increase the statistics of events $> \sim 50$ GeV by $\sim 40\%$ depending on energy. However in the best case, the events have a PSF of ~ 2 degrees.

Fermipy - an open-source python framework that facilitates analysis of data collected by the Fermi Large Area Telescope (LAT)

- built on the Fermi Science Tools, the publicly available software suite provided by NASA for the LAT mission.
- provides a high-level interface for analyzing LAT data in a simple and reproducible way. The current feature set includes methods for:
 - * extracting spectral energy distributions and lightcurves, generating test statistic maps, finding new source candidates, and fitting source position and extension.

The LAT team is working to a **new event selection which efficiently removes residual background**: heavy ion and ribbon cuts remove the non-isotropic bkg above 100 MeV a new cleaner event class is in the making and should replace the current SOURCE class

Summary

The collaboration continues to release products to the community:

~ 65 contributions (talks+posters) to the coming 7th Fermi Symposium

Expect new products coming out from the LAT team and released via the FSSC. These include new catalogs, new software, and new alerts.